RECOMMENDED PRACTICES FOR MONITORING WELL DESIGN, INSTALLATION, AND DECOMMISSIONING

FINAL

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DIVISION OF ENVIRONMENTAL QUALITY
WATER QUALITY SECTION

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RECOMMENDED PRACTICES FOR MONITORING WELL DESIGN, INSTALLATION, AND DECOMMISSIONING

PURPOSE: To provide guidance to Regional Administrators regarding recommended practices for design, installation, and decommissioning of groundwater monitoring wells.

BACKGROUND: Groundwater monitoring is required by the Alaska Department of Conservation (ADEC) at facilities regulated by many of the programs it administers. Facilities where monitoring wells may be required or used for these programs include but are not limited to the following: hazardous and solid waste facilities, underground storage tank facilities, and contaminated sites. Regional and district staff, as well as the public, have requested guidelines for the location, design, installation, documentation, and decommissioning of monitoring wells. These guidelines are intended for statewide use. They have undergone review by DEC staff and the regulated public and were developed based on monitoring well regulations and guidelines from Wisconsin, Washington, Oregon, and the U.S. Environmental Protection Agency.

APPLICABILITY: These guidelines are intended to offer direction for the installation of permanent and temporary monitoring wells installed at solid waste facilities, underground storage tank sites, contaminated sites, and other sites where groundwater monitoring well installation is required by ADEC programs. They are not regulations and are for guidance purposes only.

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PREFACE

The number of soil and groundwater investigations is increasing at a rapid rate in Alaska. Typically monitoring wells are installed to measure groundwater quality. Most of these monitoring wells are installed for, or for investigations that are submitted to, the Alaska Department of Environmental Conservation. The Department developed these recommended practices in an effort to enhance consistency in the siting, design, installation, decommissioning, and documentation of monitoring wells. Monitoring wells should be constructed in a manner to ensure groundwater samples are representative of the *in-situ* water chemistry. The Department and responsible party have to know the quality of the sampling point, in most cases a monitoring well, though in permafrost areas, well points are sometimes utilized to measure the water quality in the "active thaw zone." The results from these sample points are used to select cleanup actions which cost in the tens to hundreds of thousands of dollars, so taking measures to ensure accuracy is cost-efficient and good practice.

To be most effective, a monitoring well should provide reliable, meaningful information. The materials and techniques used for constructing a monitoring well must not materially alter the quality of the water being sampled. An understanding of the chemistry of suspected pollutants and the geologic setting in which the monitoring well is to be constructed play a major role in selecting the drilling technique and well construction material used. To this end, these recommended practices discuss developing a conceptual model of the geologic site conditions, and well design and installation. In many cases, this means that more time and money should be spent to ensure a good quality monitoring well.

These recommended practices should not be considered complete nor applicable in all situations. They are not regulations. Depending on the purpose of the well and the duration of use, a specific monitoring well, or set of wells, may not require construction to these recommended practices. The Department recognizes that regional, climatic, and geographic differences will affect monitoring well design. Because of this, there are "exception" comments with many of the sections of these recommended practices. The important point is that the quality of the sampling point should be known and documented in order to properly interpret the data from the well. This is essential for efficient design of any investigation, detection monitoring, or remediation program.

1.0 PURPOSE

These recommended practices present standards for the location, design, installation, decommissioning, and documentation of monitoring wells and well points in Alaska. Monitoring wells should be designed, located, installed, and maintained so as to obtain reliable and representative information regarding aquifer characteristics, groundwater flow directions, and chemical and physical characteristics of groundwater. The Department recognizes that the approach and technology available for monitoring are evolving. These recommended practices are not intended to limit reasonable innovation but, rather, to provide a general framework through which innovation can occur.

Monitoring well design and installation should:

(1) Include consideration of site specific hydrogeologic information from all available sources and include development of a conceptual hydrogeologic model of the site.

(2) Be compatible with site specific hydrogeologic conditions, including the physical and chemical properties of the groundwater and any contaminants known or suspected to be present in the groundwater.

(3) Prevent introduction of surface contaminants into the groundwater, prevent vertical movement of water or contaminants between water-bearing zones in either the well bore or well annulus, and prevent waste or contamination of groundwater resources.

(4) Minimize sediment and turbidity in water samples, and minimize interference to the results of water quality analyses.

(5) Maximize well efficiency where monitoring wells may later be used in the remediation of groundwater.

(6) For regulated facilities, result in permanent wells which will last for the life of the facility being monitored, including the post-closure care period.

(7) Include consideration for proper decommission when no longer in use or no longer functioning as designed, or the project is completed.

The National Water Well Association recently completed a handbook on the design and installation of monitoring wells (Aller et al, 1989). This handbook provides detailed discussion of all aspects of monitoring wells. The American Society for Testing and Materials is developing an "ASTM standard" for monitoring wells. The Department recommends that it be followed when it becomes available, with modifications as needed to meet Alaskan conditions.

2.0 APPLICABILITY

The Department recommends persons installing monitoring wells and well points to fulfill regulatory requirements of 18 AAC 15, 60, 62, 70, 71, 72, 73, 75, 78, 80, and 90 follow these recommended practices. In addition, the Department recommends these recommended practices be used when installing groundwater monitoring wells as partial fulfillment of contract terms with the Department. These recommended practices should also be used when installing monitoring wells as part of an investigation of soil or groundwater contamination. The degree to which any particular monitoring well or well point should meet these recommended practices depends on several factors. These factors include: the type of facility or investigation at which the wells are used, the expected duration of the use of the well, and site-specific conditions.

3.0 LOCATION

3.1. GENERAL. Soil mechanics, geomorphology, geologic structure, stratigraphy, and sedimentary concepts are important in siting a monitoring well or network of wells. This information must be combined with a knowledge of groundwater movement to complete the application of these recommended practices. Therefore, development of a conceptual hydrogeologic model that identifies potential flow paths and target monitoring zone(s) is recommended prior to monitoring well design and installation (see 3.3 Conceptual Model below).

One important consideration in monitoring well design is proper spatial and vertical location to ensure that the groundwater flow regime is accurately being monitored. Monitoring wells are typically installed in the uppermost permeable water-bearing zone under or adjacent to a regulated facility or potential source of contamination. Consideration should be given to natural, seasonal, and human-caused fluctuations in water table elevation. Natural fluctuations might be caused by infiltration of snowmelt or precipitation, proximity to rivers with seasonal high water levels, or tidal fluctuations. Human-caused fluctuations can result from pumping, wastewater disposal, or paving to decrease infiltration rates.

Location of the screened interval relative to the water table elevation may influence sampling results. For example, a well screened at the water table, with some screen above the water table and some below the water table, will intercept floating petroleum product, whereas a well with the top of the screened interval located below the water table will not, under static conditions.

At sites with long-term detection monitoring (more than five years) the location of each well, the elevation of the land surface, and the top of each well casing should be surveyed by a registered professional surveyor or registered civil engineer engaged in the practice of surveying. The riser pipe should be permanently marked with a reference point for water level measurements. The location survey should achieve a horizontal accuracy of 0.2 foot, and the elevation surveys should achieve a vertical accuracy of 0.01 foot. Vertical elevation control should be the National Geodetic Vertical Datum, and horizontal control should be the Universal Transverse Mercator Grid. Sites undergoing contaminant assessment monitoring with a large number of monitoring wells should have the wells surveyed as described above. Some sites with just a few wells may not need this level of detail.

3.2. GOALS OF MONITORING PROGRAM. There are several purposes for groundwater monitoring. They include ambient monitoring, source monitoring, case preparation monitoring, and research monitoring (Barcelona et al., 1983). Wells installed for each of these purposes must satisfy somewhat different requirements, and may require different strategies for well design and installation. Prior to design and installation there should be clear understanding of what the monitoring program is intended to accomplish. For further discussion of the various purposes of groundwater monitoring see U.S EPA (1987) and Maynard (1988).

3.3. CONCEPTUAL MODEL. Based on available information, the monitoring well designer should develop a preliminary hydrogeologic conceptual model of the site to be monitored. The purpose of the conceptual model is to estimate the distribution of the predominant soil and rock units and the flow conditions at the site. This is not a mathematical model nor a computer model, though either may be used to aid in understanding the hydrogeologic system. The conceptual model may include estimates of the distribution of aquifer(s) and aquitards at or near the site, hydrologic boundaries, the range of potentiometric surface(s), and other pertinent hydrogeologic properties.

The conceptual model is hypothesized initially using data obtained from a variety of sources such as a literature search, local experience, or field reconnaissance. In areas where the geology is relatively uniform, well-documented in the literature, and substantiated by field reconnaissance, further refinement of the conceptual model may not be necessary unless anomalies are discovered in the well drilling stage. The conceptual model is used in proposing the horizontal location of monitoring wells and the vertical location of the screened interval to ensure that the site is appropriately monitored. The preliminary hydrogeologic conceptual model should be updated as boreholes are completed. Should the borings reveal substantially different information on the geology, the location of monitoring wells may need to be adjusted.

4.0 DESIGN AND INSTALLATION

4.1 GENERAL. The Department recommends all monitoring wells be designed and installed by, or under the direct supervision of, a geologist, engineer, or other professional with direct experience in the design and installation of monitoring wells. The Department recommends that all monitoring wells be installed by a licensed contractor qualified and equipped to drill and construct monitoring wells.

Well design and installation should be appropriate to ensure that groundwater samples and water level measurements characterize discrete stratigraphic intervals. Well design and installation should prevent the introduction of surface contaminants into the groundwater, and prevent leakage of groundwater or contaminants between stratigraphic intervals in the well bore or along the well annulus. If leakage is detected, it should be corrected or the well should be decommissioned. Permanent or temporary surface casing should be used during well drilling and installation in all cases where contaminated groundwater could migrate in the borehole by gravity flow or under artesian pressure into other water-bearing zones, or where the formations penetrated have a tendency to slough or cave into the borehole and affect filter pack and annular seal placement or integrity.

Monitoring wells may be placed individually or in well clusters. Well clusters should consist of individual wells in close proximity, screened at varying depths, each installed in its own borehole. Wells consisting of multiple aquifer completions in a single borehole are not recommended. This is not to exclude multiple port wells in a single casing.

Appropriate measures should be taken to protect all monitoring wells from loss of integrity by soil erosion, soil settlement, shrink-swell soil conditions, frost heaving of soils, damage by vehicles or heavy equipment, and other site specific hazards. Monitoring wells should not be installed in locations where they are subject to periodic or seasonal inundation by floodwaters, unless steps are taken for special watertight construction. The Department discourages persons from completing monitoring wells at- or below-grade unless it is necessary for a site investigation or Underground Storage Tank monitoring, because of the potential for leakage into the well.

4.2 WELL MATERIALS. (1) PURPOSE. Monitoring wells and well points should be constructed of new materials that will not chemically, physically, or biologically affect the groundwater quality or be deleteriously affected by the subsurface environment.

(2) SPECIFICATIONS. The casing should be nonreactive with the subsurface environment and any contaminant the monitoring well may encounter. All casing, well screen and riser pipe should be thoroughly cleaned prior to installation in the well, and should be centered in the borehole. The casing should not affect or interfere with the chemical, physical, radiological, or biological constituents of interest. All monitoring well casing should

conform to ASTM Standards, and will generally be constructed of polyvinyl chloride (PVC), stainless steel, fluoropolymer, or fiberglass materials.

The inside diameter of all well screens and riser pipes should be at least 1.9 inches, except as noted below. The collapse strength of all casing and riser pipe used in monitoring well construction should be great enough to withstand the pressure exerted by the annular seals during seal placement, under conditions when the casing or riser pipe is evacuated of fluid. All PVC used in monitoring well construction should conform to ASTM F-480, Standard Specification for Thermoplastic Water Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR). Screen and riser pipe assemblies should not contain dissimilar metals, unless separated by a dielectric bushing. Riser pipes should extend to a minimum height of eighteen (18) inches above land surface, except for flush mounts. Riser pipes should be sealed with caps and vented to allow for pressure equalization.

Well screens should be installed in all monitoring wells. All screens should be machine-slotted or continuous wrapped wire-wound. Well screens, riser pipes, casings, annular seals, and other components of the monitoring well should be composed of new materials selected to last for the life of the facility being monitored (including the post closure care period), or the duration of an investigation without contributing contaminants to the groundwater, or loss of structural integrity. Hand cut screens should not be used. The Department recommends that, in general, well screens not exceed ten (10) feet in length, or for piezometers, five (5) feet.

The slot size of the screen should be compatible with the grain size of the filter pack (the screen should be capable of retaining at least ninety (90) percent of the filter pack). Water table variations, site stratigraphy, expected contaminant behavior, and groundwater flow should be considered in selecting the screen composition, length, and position in the borehole. Where existing contamination is suspected or known, downhole geophysical techniques or groundwater sampling may be necessary to aid in selecting the location of the screened interval. Centering guides should be used to center the well screen in the borehole in deeper wells.

Bottom caps or end plugs should be used on all monitoring wells. Joints, caps, and end plugs should be watertight and secured by welds, threads, or force fittings. Solvents, glues or adhesives should not be used for riser pipe or screen assembly. Well casings should be flush fit on the inside. Monitoring wells installed in competent (non-collapsible) bedrock may be constructed without a well screen.

(3) EXCEPTIONS. Well screens not meeting the requirements of this section may be installed, though, in general, is not recommended by the Department. Riser pipe and well screens for piezometers may be less than 1.9 inches in diameter.

4.3 DRILLING AND SAMPLING METHODS. (1) PURPOSE. Monitoring wells should be installed using proper drilling methods and techniques to avoid introducing contamination or impairing the hydraulic connection between the formation and the well. Improper well installation may cause inaccurate or unrepresentative groundwater sample results.

(2) SPECIFICATIONS. Every appropriate precaution should be taken during drilling and sampling of monitoring wells to avoid introducing contaminants into the borehole. Avoid using drilling mud, synthetic drilling fluids, petroleum- or metal-based pipe joint compounds, and other potential contaminants unless absolutely necessary.

Air drilling systems should have in-line air filters in good working order to remove compressor oils entrained in the air stream. If it is necessary to add water to the borehole during drilling, only potable water should be used, and the source of the water should be identified. If it is necessary to add drilling mud to the borehole during drilling to stabilize the hole or control downhole fluid losses, only high yield sodium bentonite clay free of all organic polymer additives should be used.

All equipment placed into the borehole should be properly decontaminated by steam cleaning, high pressure hot water, or similar method before and after use at the site and between boreholes. When possible, upgradient wells should be drilled first. Any contaminated cuttings or water removed from the borehole during drilling should be properly managed.

Boreholes should have a minimum inside diameter at least four inches larger than the maximum outside diameter of the riser pipe and screen, to ensure that a tremie pipe may be properly used in the well, and to ensure an adequate annular seal.

Formation samples (if they are collected) should be collected during drilling, preferably using techniques to recover minimally disturbed samples. Appropriate sampling techniques will depend on the drilling method used and the goals of the sampling. Soil samples should not be composited for testing purposes. Additional sampling to determine the presence and concentration of contaminants in soil samples may also be necessary to define the limits of contamination.

Sampling techniques for hollow-stem auger drilling include continuous split barrel core samples, shelby tube (ASTM D-1587), or split spoon (ASTM D-1586) samples. Sampling techniques for rotary drilling include shelby tube samples, split spoon samples, wireline or conventional core samples (ASTM D-2113), or grab samples. Sampling techniques for cable tool drilling include bailer grab samples. The Department recommends formation samples be collected every five (5) feet, or at every change of formation, whichever interval is smaller, to the total depth of the hole, except as noted in part 3 of this section.

When installing well clusters, the deepest well in the cluster should be drilled first. Samples should be collected during drilling as described above; shallower wells in the cluster should be drilled after the deepest well and may not need formation samples to define lithology. Sampling may be required to determine contaminant levels during the drilling of all wells. Sampling information from the deeper borehole may be used to determine what interval of the formation should be screened, or where to place seals to prevent communication between aquifers.

If any borehole is drilled deeper than the well to be completed in the borehole, the borehole should be sealed to within one (1) foot of the bottom of the completed interval by a method described in Section 5.0 Decommissioning below. Temporary casing or auger flights may be used to prevent caving of the borehole prior to grouting. Following installation, the top of the seal should be sounded to check for proper placement. The seal should be allowed sufficient time to set or hydrate before completing the well in the borehole above the seal. Any borehole that is drilled and not completed as a monitoring well, and is covered in the applicability section, should be sealed immediately following drilling, from the bottom of the borehole to land surface using a method described in Section 5.0 Decommissioning, below.

(3) EXCEPTIONS. For site investigations in relatively consistent, uniform geologic settings, formation samples from every borehole may not be required when boreholes are drilled in close proximity. Additional detailed sampling may not be necessary if detailed sample logs have already been obtained from previous borings drilled in the vicinity of the monitoring wells as part of a hydrogeologic site characterization study. Although, in general, the

Department recommends the maximum interval between samples not exceed five (5) feet, the actual maximum sampling interval may be greater depending on the uniformity of the geology and the overall depth of the well.

4.4 FILTER PACKS. (1) PURPOSE. The filter pack should minimize the amount of fine materials entering the well, allow for proper well development, and should not inhibit the inflow of water to the well.

(2) SPECIFICATIONS. All permanent groundwater monitoring wells installed in unconsolidated material and used for the collection of water quality samples should be constructed with filter packs. Permanent groundwater monitoring wells installed in bedrock may be constructed without filter packs. When used, the filter pack should be the only material in contact with the well screen. All commercially prepared filter packs installed in permanent groundwater monitoring wells should meet the requirements of this section.

The filter pack surrounding the well screen should consist of clean, chemically inert, well-rounded, siliceous material. Filter fabrics should not be used in conjunction with, or in place of, filter packs. The sand or gravel used for filter packs should be hard and durable and should have an average specific gravity of not less than 2.50. The sand and gravel should be visibly free of clay, dust, and organic matter. Not more than five percent of the sand or gravel should be soluble in hydrochloric acid. Thin, flat, or elongated pieces of gravel, the dimension of which exceeds three times the minimum dimension, should not constitute more than two percent of the material by weight. The filter pack for wells installed in unconsolidated material should be sized to retain most of the surrounding formation. In unconsolidated material, the filter pack should be either a coarse or medium sand. In bedrock, the filter pack should be a medium or coarse sand or gravel. Do not use crushed limestone or dolomite, material containing clay, or any other material that may adversely impact the performance of the monitoring well.

For wells screened in water-bearing zones composed of non-cohesive granular materials, the grain size of the filter pack should be based upon a representative sieve analysis of the formation materials opposite the well screen. The filter pack is usually selected to have a 30% finer (d-30) grain size that is about four to ten times larger in size than the 30% finer (d-30) grain size of the formation materials being filtered. Usually, the filter pack is selected to have a uniformity coefficient less than 2.5.

Standard filter packs for a particular screen size may be used if the filter pack characteristics approximate those described above. Alternative methods of choosing filter pack materials may be necessary when the monitoring wells are screened in consolidated rock or in very fine grained sandy or silty formations. The filter pack should be placed using a method that ensures positive placement opposite the well screen without bridging or size segregation of the filter pack material, such as a tremie pipe or other similar method. No filter pack is required for driven well points.

(3) INSTALLATION. The filter pack should extend from one foot beneath the well end cap to two feet above the top of the well screen. The required filter pack height above the top of the well screen may be reduced to six inches to allow for the required volume of annular space sealant to be placed.

Calculations should be made prior to filter pack placement to determine the volume of filter pack material needed to fill the annular space to the appropriate depth. Following installation, the top of the filter pack should be sounded to check for proper placement. A finer-grained sand filter six (6) inches thick may be placed at the top of the filter pack, and below the bentonite seal, to help prevent infiltration of the bentonite into the filter pack.

(4) EXCEPTIONS. Alternate filter pack designs and installation procedures may be more suitable than the method recommended above, depending upon the geologic setting and use of the well. The natural formation may be acceptable as filter pack material if the physical and chemical properties of the formation are consistent with the filter pack specifications stated in paragraph 2 of this section and will limit the passage of formation fines into the well screen. The grain size distribution of the formation should be such that at least 50 percent of the formation will be retained by the well screen. If used as filter pack the material should be visibly free of clay, dust, and micaceous and organic matter, and be free of contamination.

4.5 WELL SEALS. (1) PURPOSE. Well seals are installed to prevent the transmission of water or contaminants up or down boreholes or along well casings.

(2) SPECIFICATIONS. The fluid sealant should be installed with a tremie tube from the bottom up. Use only potable water to hydrate the mixture. All materials and procedures used in the installation of seals for permanent groundwater monitoring wells should meet the requirements of this section.

(3) TOP OF FILTER PACK SEAL. (a) Specifications. All permanent monitoring wells installed with filter packs should be constructed with a seal at the top of the filter pack. The seal should extend a minimum of two feet upward from the top of the filter pack. The filter pack seal should consist of bentonite pellets, bentonite slurry, or similar material. The thickness of the seal may be reduced to less than two feet if necessary to allow for the required volume of filter pack to be placed.

(b) Installation. When bentonite pellets are used, the top of filter pack seal should be installed in sequential one foot thick layers. Where bentonite pellets are used above the water table, each one foot layer should be hydrated by pouring water down the borehole before the next layer of pellets is put in place. This process should continue until the required seal thickness is installed. A tape measure, measuring rod or similar device should be used to ensure that the filter pack seal is installed over the proper depth interval.

(4) ANNULAR SPACE SEAL. (a) Specifications.

1. All permanent monitoring wells should be installed with an annular space seal that has a permeability of $1X10^{-7}$ centimeters per second or less. For permanent monitoring wells completed with filter packs, the annular space seal should extend from the top of the filter pack to the ground surface concrete seal and should be at least two feet thick. The annular space should be sealed with one of the following materials:

   a. Neat cement grout (not recommended for use with schedule 40 PVC well casing nor where there maybe shrinkage that may allow leakage along the casing.),
   b. Sodium based bentonite slurry with a mud weight of at least 10.00 pounds per gallon,
   c. Sodium based bentonite granules,
   d. Sodium based bentonite pellets, and
   e. Bentonite - cement grout.

2. Bentonite pellets or granules may be used to seal the annular space under the following restrictions:

a. Granular bentonite can be used when there is no standing water in the well above the top of the filter pack seal and the total well depth is less than 25 feet.

b. Bentonite pellets can be used when the depth of standing water in the well is less than 30 feet and the total well depth is less than 50 feet.

(b) Installation.

1. When bentonite pellets or granules are used to seal the annular space they may either be poured freely down the borehole or added through a tremie pipe. They should be placed so as to not form bridges, gaps, or channels.

2. When the approved grouts or slurries are used to seal the annular space the following procedures should be used.

a. For wells less than 40 feet in depth the material may be poured freely down the borehole with or without the use of a tremie pipe. If there is greater than 10 feet of standing water in the well a tremie pipe should be used to install neat cement and bentonite-cement grouts.

b. For wells 40 feet or greater in depth the material should be pumped down the borehole using a tremie pipe.

3. In all instances where a tremie pipe is used to install a slurry or grout, the lower end of the pipe should remain submerged in the sealing material during the

installation process. The Department recommends that when a slurry or grout is used there should be a 24-hour period between the time the annular space seal is installed and the time the protective cover pipe is installed. Any settling in the annular space seal should be filled before the protective cover pipe is installed.

(5) GROUND SURFACE SEAL. (a) Specifications. All permanent monitoring wells should be constructed with a concrete ground surface seal. The ground surface seal should extend to a minimum of 60 inches below the land surface, where practicable, and the top should slope away from the well casing. The ground surface seal should be installed around the protective cover and should not be placed between the protective cover and the well casing. In situations where permafrost or seasonal frost may cause problems, alternative ground surface seals may be appropriate.

(6) EXCEPTIONS. Alternative sealing procedures may be used to seal the annular space, if they provide equivalent protection. In areas with shallow groundwater the minimum thickness of seals may be reduced.

4.6 SURFACE PROTECTION MEASURES (1) PURPOSE. Permanent monitoring wells should be constructed so the above-ground portion of the well is protected from damage that may affect sampling.

(2) SPECIFICATIONS. (a) Every monitoring well should be capped using a lockable cover, or equivalent, and protected using one of the following methods:

1. If the well is cased with metal and completed above the ground surface, a lockable cap should be attached to the top of the casing.

2. If the well is not cased with metal and completed above the ground surface, a metal protective casing should be installed around the well. The protective casing should extend at least six inches above the top of the well casing and at least two feet into the ground. A lockable cap should be attached to the top of the protective casing.

3. If the well is completed below ground surface, a lockable "water-meter cover" or equivalent, should be installed around the well. A protective cover, level with the ground surface, should be installed with a waterproof seal to prevent the inflow of surface water. The cover should be designed to withstand the maximum expected loadings.

(b) Guard posts should be installed where monitoring wells are completed above ground and installed in areas where they may be needed to protect the wells from damage. The guard posts should consist of three metal posts at least three inches in diameter, and set in concrete. They should be installed in a triangular array around the casing and at least two feet from it. Each post should extend at least three feet above and below the ground surface. The above-ground portion should be painted with a bright colored paint.

(c) Other surface protection methods may be used if they meet the intent of protecting the above-ground portion of a monitoring well.

(d) If the well is damaged, the well protection measures and casing should be restored as prescribed by this chapter. If the well is damaged beyond repair, it should be properly decommissioned.

4.7 WELL DEVELOPMENT. (1) PURPOSE. Well development is important for removing any mud "cake" that may have formed on the water bearing formation during drilling and to ensure the well provides water free of suspended solids.

(2) SPECIFICATIONS. The Department recommends that all wells be developed as soon as possible after installation, but not before the well seals and grout have set. In general, wells should be developed more than 24 hours after installation. The objective of well development is to remove any water or drilling fluids introduced into the well during drilling, stabilize the filter pack and formation materials opposite the well screen, minimize the amount of fine materials entering the well, and maximize the efficiency of the well and the inflow of water to the well. The entire submerged portion of the screened interval should be developed.

Development may include the use of surge blocks, bailers, or other equipment that frequently reverses the flow of water through the well screen and prevents bridging of formation or filter pack particles. An important factor in any method is that the development work be started slowly and gently and be increased in vigor as the well is developed. Most methods of well development require the application of sufficient energy to disturb the filter pack, thereby freeing the fines and allowing them to be drawn into the well. The coarser fractions then settle around and stabilize the screen. The well development method chosen should be documented on the well completion log.

During development, water or air should not be introduced into the well. Any contaminated water withdrawn during development should be properly managed. Development should not disturb the annular seal or the formations above the water-bearing zone, or damage the well. Special development techniques that minimize agitation and disturbance of the formation materials may be required in monitoring wells that screen very fine-grained sands or silt formations. Development should be considered complete only when the water removed from the well is as free of sediment as possible. If water reasonably free of sediment cannot be obtained from the well following development, additional well development or replacement of the well may be necessary.

(3) WELLS THAT CANNOT BE PURGED DRY. All groundwater monitoring wells that cannot be purged dry should be developed by the following procedure:

(a) Alternately surge and purge the well. The surge and purge cycle should consist of several minutes of surging followed by several minutes of purging to remove the fine material collecting in the bottom of the well. This cycle should be continued for a minimum of 30 minutes. The surging should forcefully move formation water in and out of the well screen. The surging should be accomplished by using either a surge block or bailer or by pumping the well sufficiently to cause a drawdown and then allowing the well to recover and repeating the process. The Department recommends that air surging not be used.

(b) After surging, the well should be pumped until 10 well volumes of water are removed or until the well produces sediment free water.

(4) WELLS THAT CAN BE PURGED DRY. All permanent groundwater monitoring wells that can be purged dry should be developed by first purging the well dry and then adding one well casing volume of potable water to the well. After the water is added, the well should be surged vigorously for 10 minutes by using either a surge block or bailer. Additional water may be added as necessary to properly develop the well. After surging the well, it should be purged dry again to complete the development process. Water should be added as a last resort. If the well will recover, continued development should occur only with formation water.

(5) EXCEPTIONS. Alternate development procedures may be used if they will not affect the ability of the well to provide representative samples. At locations where a second trip to the well is for the sole purpose of well development and the travel distance is far, well development may occur less than 24 hours after well installation, allowing as much time as possible to pass between installation and development.

4.8 DRIVE POINT WELLS. (1) PURPOSE. For certain conditions drive point wells provide efficient sampling points.

(2) SPECIFICATIONS. Drive point wells with galvanized steel drive points may be used as permanent groundwater monitoring wells with the following restrictions. When used on projects that meet the applicability requirements of Section 2.0, written documentation should be supplied to the Department after installation indicating that the well is to be used for only the following:

(a) for water table elevation measurements,
(b) to monitor parameters with which the casing will not interfere,
(c) where the drive point will not provide a conduit for contaminants to enter the groundwater, and
(d) where information on subsurface stratigraphy is not needed.

In situations where subsurface geologic information is needed, a separate borehole should be advanced to collect the required data.

4.9 MONITORING WELLS IN, THROUGH, OR ABOVE PERMAFROST (1) PURPOSE. In certain portions of Alaska, groundwater monitoring requires the installation of monitoring wells in, through, or above permafrost. This sections describes possible modifications of monitoring wells for the potential effects of permafrost.

(2) SPECIFICATIONS. Monitoring wells should be designed and constructed to minimize their effect on the subsurface thermal regime and to withstand freeze-thaw forces. Monitoring wells that penetrate permafrost should be maintained so that representative groundwater samples can be collected during any time of the year. Monitoring wells installed into permafrost (ie. screened in the seasonal active layer) should be designed and constructed to obtain a representative groundwater sample during the period of thaw. The latter wells should be screened deeper than the greatest expected depth of thaw to prevent them from going dry late in the thawing season.

Artesian wells in permafrost regions require special attention. Groundwater that rises in the casing up into the permafrost zone may freeze; if heat or compressed gas are considered or used to prevent freezing, their impact on volatile constituents in the water or soil should be considered and minimized. In addition, the thawed annulus between the pipe and the permafrost must be firmly sealed to prevent seepage upward from the confined aquifer.

4.10 TEMPORARY MONITORING WELLS. (1) PURPOSE. During site investigations temporary monitoring wells may be installed to help define the nature and extent of contamination.

(2) SPECIFICATIONS. Temporary groundwater monitoring wells may be installed according to standards less stringent than those specified for permanent monitoring wells. However, care should still be taken that the wells provide samples representative of the *in-situ* groundwater quality. All temporary monitoring wells should be decommissioned following procedures recommended in this document within 60 days after their installation.

5.0 DECOMMISSIONING

5.1 GENERAL. Any well installed under the applicable requirements listed in Section 2.0 which is unusable, or which use has been permanently discontinued, or which is in such disrepair that its continued use is impractical or is an environmental, safety or public health hazard should be decommissioned. The decommissioning procedure should be recorded and reported as requested by the Department.

Each monitoring well should be permanently decommissioned by sealing with grout, or equivalent, at the end of the post-closure care period, when no longer in active use, when irreparable leakage in the well or annular space is known or suspected, or when the integrity of the well is permanently compromised in some other manner.

5.2 METHODS.(1) PURPOSE. Wells should be decommissioned by completely sealing the well bore to prevent the entrance of surface contaminants into the groundwater. Decommissioning must also to prevent vertical movement of water or contaminants between water-bearing zones in both the well casing and the annular space.

(2) SPECIFICATIONS. Wells that were not constructed in accordance with the practices recommended in this guidance or other comparable U.S. Environmental Protection Agency or accepted standard, or wells that are decommissioned to permit the installation of potential sources of contamination (such as solid waste management units) within one hundred feet of the well, should be decommissioned in one of three ways:

(a) Perforate the casing from the bottom to within five feet of the land surface, remove the casing from five feet below the surface to the surface, and pressure grout the casing with enough grout to fill the annulus. Perforations should be spaced with at least four equidistant cuts per row, and one row per foot. Each cut should be at least one and one-half inches long. Shot perforations may also be used.

(b) Withdraw the casing and fill the bore hole with grout or bentonite as the casing is being withdrawn.

(c) An alternative method approved by the department or conforming to ANSI/AWWA Standard A100-84 (Eff 6/14/91, Register 118).

Pipe sealing materials directly to the point of application or emplace by means of a dump bailer or tremie tube. If cement grout, neat cement, or puddled clay are used as sealing materials below the static-water level in the well, they should be placed from the bottom up using methods that avoid segregation or dilution of the material. When a tremie tube is used to place grout, the discharge end should be submerged in the grout to avoid breaking the seal while filling the annular space. For artesian wells, a cement grout or concrete plug should be placed in the confining stratum overlying the artesian zone to prevent upward seepage from the artesian zone. The remainder of the well should be filled with cement grout or bentonite.

(3) EXCEPTIONS. For wells where the water table is greater than 50 feet below the land surface, clean sand may be substituted for grout in the interval between 10 feet above the seasonal high water table and 10 feet below the land surface.

6.0 DOCUMENTATION

6.1 GENERAL. The purpose of documentation is provide a record of the well design and installation, and the materials used. This information may be useful in determining, at a later date, if the monitoring well design, installation, or history may be affecting sampling results or the interpretation of site conditions. Unconsolidated deposits should be classified on the borehole log according to the Unified Soil Classification System (USCS), and described in detail according to their texture, color, mineralogy, moisture content, degree of weathering, geologic origin, and other relevant characteristics. The USCS visual method should be used to classify all samples, supplemented by appropriate USCS laboratory tests (ie. mechanical and/or hydrometer grain size tests and Atterberg limits) on a representative number of samples from each stratigraphic unit. A clear description of the classification system used should be included with the log. Descriptions should conform to ASTM D-2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) and ASTM D-2487, Standard Test Method for Classification of Soils For Engineering Purposes.

Rock core logs should describe the lithology, mineralogy, color, grain size, degree of cementation, degree of weathering, density and orientation of fractures, other primary and secondary features and physical characteristics of the rock, and the rock quality designation. When possible, a clear, labeled, photographic record of all rock cores should also be taken and submitted with rock core logs.

The decommissioning procedure should be documented. The following information, at a minimum, should be submitted to the Department: Project name, if appropriate; date; location of well by 1/4, 1/4, section or smallest legal subdivision; latitude and longitude; well identification number; use of well; method of setting the plug; type and amount of sealant used; and other information as required by the Department.

A facility or project-unique identification number should be permanently attached or engraved on the inner and outer well casings. The number should consist of a local well number assigned by the project personnel. The Department recommends that a statewide-unique USGS site identification number be obtained for each monitoring well, in addition to a local well number. Copies of all borehole logs should be sent a copy to the Division of Geological and Geophysical Surveys, Department of Natural Resources, P.O. Box 772116, Eagle River, AK. 99577.

6.2 BOREHOLE LOG. A detailed log should be submitted for all boreholes drilled. The log should include the following:

(1) project name,
(2) basic site sketch,
(3) borehole number,
(4) the location of the hole-including,
  a. legal description - i) subdivision, lot, block, or tract information, or ii) section lot, tax lot or government lot number,
  b. meridian, township, range, section, and 1/4, 1/4, 1/4, 1/4 locations within section,
  c. latitude and longitude, to the nearest second, and
  d. state plane coordinates (if available),
(5) date and time drilling started and finished,
(6) driller's name and affiliation,
(7) site geologist's name and affiliation,
(8) elevation of the land surface surveyed to the nearest 0.1 foot (for those sites where

a site survey is completed),

(9) size (diameter) and total depth of the hole,

(10) type of drilling rig and method of drilling,

(11) type and volume of drilling fluids or additives used, if applicable,

(12) penetration rate or standard penetration resistance, if measured,

(13) sample intervals and percent recovery,

(14) stratigraphic and lithologic information, using Unified Soil Classification System,

(15) depth to water during drilling,

(16) depth to water after water level has stabilized following drilling,

(17) zones of high-permeability or fractures encountered,

(18) contamination observations,

(19) indication of whether frozen ground, ice, or permafrost was encountered. If so, a description,and

(20) any other drilling observations including lost circulation zones or other difficulties encountered during drilling.

6.3 MONITORING WELL COMPLETION LOG. A detailed completion log should be submitted to DGGS for all boreholes drilled. The log should include the following as-built data:

(1) project-unique monitoring well number,

(2) elevation of ground surface and measuring point,

(3) project name,

(4) well installed by,

(5) drilled by,

(6) date construction started and completed,

(7) total depth drilled,

(8) drilling method,
(9) borehole diameter,
(10) diameter and length of the protective cover pipe,
(11) the type of cap and lock,
(12) quantity of filter pack material used,
(13) manufacturer and product name of the filter pack material,
(14) type and quantity of annular space material used and the source and quantity of any water added or removed from the well during development, including information on the size and depth of the hole,
(15) depth of the completed well,
(16) screen type, material, diameter, slot size and percent open area, and location of the top and bottom of the screened interval,
(17) riser pipe material and diameter,
(18) type of joints or fittings used to assemble screen and riser pipe,
(19) the static water level measured to the nearest 0.01 foot, with the date of measurement, and
(20) type of development, time development started and finished.

Readings for field temperature, field specific conductance and field pH should be reported. The well constructor should report any decontamination procedures used between well installations.

6.4 SITE MAP. All well locations should be indicated on a plan map drawn to a specified scale. The site map should include:

(1) facility and property boundaries,
(2) buildings and roads,

(3) exploratory borings and monitoring wells,

(4) nearby surface water,

(5) legend with location of cross-section, and

(6) bar scale and north arrow.

In addition to the above, an 8.5 inch by 11 inch map should be submitted showing the general location of wells and facilities on site. Following installation of the wells, an as-built plan map should be submitted specifying the surveyed location of the wells. The vertical location of the top of the well pipes should be referenced to the nearest benchmark for the National Geodetic Survey datum to an accuracy of 0.01 feet, for those sites where a site-specific survey was completed. This plan should show the exact location of the installed well(s) on a horizontal grid system which is accurate to within one foot. The plan should show the wells in relation to each other, to property boundaries, and to a common reference point on the horizontal grid system. Direction of groundwater flow should be indicated. For those sites where the well locations are not surveyed, the site map should give the approximate location.

6.5. CONCEPTUAL MODEL. One or more hydrogeologic cross-sections should be developed to refine the preliminary hydrogeologic conceptual model. The cross-sections should include:

(1) plots representative of the soil and rock observed in the exploratory borings,

(2) a legend describing the soils using the Unified Soil Classification System,

(3) plot of the borehole depth,

(4) plot of the monitoring well screen interval, if applicable,

(5) groundwater elevation and date of observation, and

(6) horizontal and vertical scale, with units identified.

7.0 REFERENCES

Aller, L., T.W. Bennett, G. Hackett, R.J. Petty, J.H. Leher, H.Sedoris, D.M. Nielsen. 1989. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. National Water Well Association. Dublin, Ohio.

Barcelona, M.J., J.P. Gibb, J.A. Helfrich, and E.E. Garske. 1985. Practical Guide for Ground-Water Sampling. Illinois State Water Survey. U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory. EPA/600/2-85/104. 169 pp.

Maynard, D. L. 1988. An Evaluation of Ground-Water Quality Monitoring in Alaska. Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys. Report of Investigations 88-12. 39 pp.

U.S. EPA. 1987. Handbook, Ground Water. U.S. Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory. EPA/625/6-87/016. 212 pp.

8.0 DEFINITIONS

For the purpose of these recommended practices the following definitions apply.

(1) "Active thaw layer" means the surface layers of organic matter and mineral soil which thaw each year in areas of permafrost.

(2) "Annular space seal" means the following: (a) for wells constructed with filter packs, it

is the material placed above the top of the filter pack seal up to the surface concrete seal, and between the well casing and the adjacent formation; (b) for wells constructed in bedrock formations and without well screens, it is the material placed from the bottom of the enlarged drillhole up to the surface concrete seal, and between the well casing and the adjacent formation.

(3) "Aquifer" means geologic formation, group of formations, or part of a formation that is saturated, and is capable of providing a significant quantity of water.

(4) "Aquitard" means lithologic unit that impedes groundwater movement and does not yield water freely to wells or springs but that may transmit appreciable water to or from adjacent aquifers. Where sufficiently thick, aquitards may act as groundwater storage zones.

(5) "Assessment monitoring" means an investigative monitoring program that is initiated after the presence of a contaminant in groundwater has been detected. The objective of this program is to determine the concentration of constituents that have contaminated the groundwater and to quantify the rate and extent of migration of these constituents.

(6) "ASTM" means American Society for Testing and Materials.

(7) "Bailer" means a hollow tubular receptacle, fitted with a check valve at the bottom, used to facilitate withdrawal of fluid from a well or borehole.

(8) "Bedrock" means the solid rock underlying any loose superficial material such as soil, alluvium, or glacial drift. Bedrock includes but is not limited to limestone, dolomite, sandstone, shale, and igneous and metamorphic rock.

(9) "Bentonite - cement grout" means a mixture of five pounds of sodium based montmorillonite clay with 94 pounds of portland cement and five to six gallons of water.

(10) "Bentonite slurry" means a mixture of sodium based montmorillonite clay and water that has a minimum mud weight of 10 pounds per gallon.

(11) "Borehole" means a circular hole deeper than it is wide constructed in earth material for the purpose of either installing a well or obtaining geologic or groundwater related data. Borehole has the same meaning as drill hole.

(12) "Borehole log" means the record of geologic units penetrated, drilling progress, depth, water level, sample recovery, volumes and types of materials used, or other significant observations regarding the drilling of an exploratory borehole or well.

(13) "Casing" means pipe, finished in sections with either threaded connections or beveled edges to be field welded, which is installed temporarily or permanently to counteract caving, to advance the borehole, and/or to isolate the zones being monitored.

(14) "Casing, Protective" means a section of large diameter pipe that is emplaced over the upper end of a smaller diameter monitoring well riser or casing to provide structural protection to the well and restrict access to the well.

(15) "Casing, Surface" means pipe used to stabilize a borehole near the surface during and following the drilling of the borehole.

(16) "Centralizer" means a device that assists in the centering of a casing or riser within a borehole or another casing.

(17) "Clay" means an inorganic soil having a grain size less than .074 millimeters (mm) and a plasticity index of 7 or more.

(18) "Clay slurry" means a mixture of clay and water.

(19) "Coarse sand" means a well-sorted sand with a predominant grain size between 4.76mm and 2.0mm as established by the Unified Soil Classification System.

(20) "Concrete grout" means a slurry mixture of 94 pounds of cement, equal volumes of dry sand and gravel, and five to six gallons of water. The ratio of sand and gravel should not exceed three parts to one.

(21) "Department" means the Alaska Department of Environmental Conservation.

(22) "Detection monitoring" means a program of monitoring for the express purpose of determining whether or not there has been a contaminant release to groundwater.

(23) "Drillhole" means the same as borehole.

(24) "Filter pack" means a clean silica sand or sand and gravel mixture of rounded grains with a selected grain size and gradation that is installed in the annular space between the borehole wall and the well screen, extending an appropriate distance above the screen, for the purpose of retaining and stabilizing the particles from the adjacent strata. The term is used in place of "gravel pack."

(25) "Fine sand" means a well-sorted sand with a predominant grain size between .42mm and .074mm as established by the Unified Soil Classification System.

(26) "Flush-joint or flush-coupled" means casing or riser with ends threaded such that a consistent inside and outside diameter is maintained across the threaded joints or couplings.

(27) "Gravel" means an unconsolidated material with the predominant grain size being between 76.2mm and 4.76mm as established by the Unified Soil Classification System.

(28) "Groundwater" means subsurface water permanently or seasonally occurring in the zone of saturation.

(29) "Grout" means a low-permeability material placed in the annulus between the well casing or riser pipe and the borehole wall (ie., in a single cased monitoring well), or between the riser and casing (i.e., in a multi-cased monitoring well), to maintain the alignment of the casing and riser and to prevent movement of groundwater or surface water within the annular space.

(30) "Inside diameter" means the distance, perpendicular to the long axis of the casing, between the inner walls of either a well casing, hollow stem auger, or tremie pipe.

(31) "Medium sand" means a well sorted sand with a predominant grain size between 2.0mm and .42mm as established by the Unified Soil Classification System.

(32) "Monitoring well" means any cased excavation or opening into the ground made by digging, boring, drilling, driving, jetting or other methods for the purpose of determining the physical, chemical, biological, or radiological properties of groundwater.

(33) "Montmorillonite" means a group of expanding lattice clay materials of the general formula: $R_{.33}\ Al_2Si_40_{10}(OH)_2 \circ H_2O$ where R includes one or more of the cations NA^+, K^+,

Mg^{+2}, Ca^{+2} and possibly others.

(34) "Neat cement grout" means a slurry mixture of 94 pounds of portland cement mixed with 5 to 6 gallons of water.

(35) "Permafrost" means subsurface material in which the naturally occurring temperature has remained below 0 degrees C (32 degrees F) for two or more consecutive years.

(36) "Permanent groundwater monitoring well" means any groundwater monitoring well in place for 60 days or longer.

(37) "Piezometer" means a well installed for the specific purpose of determining the elevation of the potentiometric surface.

(38) "Piezometric surface" has the same meaning as potentiometric surface.

(39) "Potentiometric surface" means an imaginary surface representing the total head of groundwater and is the level to which water will rise in a well.

(40) "Purge" means an action that removes water from a well, commonly accomplished using a pump or bailer.

(41) "Reagent grade water" means water that has been treated to remove any impurities that may affect the quality of sample analysis.

(42) "Riser pipe" means the pipe extending from the well screen to or above the ground surface.

(43) "Rotary drilling method" means a drilling method whereby the drillhole is constructed to the depth of casing setting. The permanent well casing is set to the bottom of the drillhole and is not driven.

(44) "Sediment sump" means a blank extension beneath the well screen used to collect fine-grained material from the filter pack and adjacent strata. The term is synonymous with rat trap or tail pipe.

(45) "Sodium based bentonite" means a clay consisting of at least 85 percent sodium montmorillonite.

(46) "Specific gravity" means the weight of a particular volume of substance compared to the weight of an equal volume of water at a reference temperature.

(47) "Static water level" means the elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping or conditions related to well installation, hydrologic testing, or nearby pumpage.

(48) "Surge" means an action causing water to move rapidly in and out of the well screen, thereby removing fine material from the surrounding aquifer. Surging is commonly accomplished by moving a surge block rapidly up and down under water inside the well casing near the well screen.

(49) "Target monitoring zone," in detection monitoring programs, means the groundwater flow path from a particular area or facility in which monitoring wells will be screened. The target monitoring zone should be a stratum (strata) in which there is a reasonable expectation that a vertically placed well will intercept migrating contaminants.

(50) "Teflon" means the registered trademark of the DuPont Company for the compound polytetrafluoroethylene.

(51) "Temporary groundwater monitoring well" means any groundwater monitoring well in place for less than 60 days.

(52) "Top of bedrock" means the top of firm rock. Firm rock is indicated by at least 70 percent of the drill cuttings being either (1) angular rock fragments, as in the case of crystalline rock or (2) rock fragments composed of individual grains or rock particles that are cemented together to form an aggregate.

(53) "Top of filter pack seal" means the sealing material placed in the annular space above the filter pack and below the annular space seal. The seal should be two feet in length and should consist of bentonite pellets.

(54) "Tremie pipe" means a metal pipe or steel wire-braided, rubber-covered hose used to convey well construction materials down a drillhole. Drill stem is acceptable to use as a tremie pipe, as long as it has been thoroughly cleaned of oil, solvents, or other contaminants.

(55) "Unconsolidated material" means that material found above firm bedrock, composed of single sediment particles, individual grains or rock fragments. Unconsolidated material includes but is not limited to clay, silt, sand, gravel, loess, peat and organic soil. For the design of a monitoring well network it is important to know the origin and depositional environment of the material.

(56) "Unified Soil Classification System" means the soil designation system based on the

physical properties of the soil developed from the Airfield Classification System in 1952 and adopted by the United States Army Corps of Engineers.

(57) "Water table" means the surface of unconfined groundwater where the pressure is equal to atmospheric pressure.

(58) "Water table observation well" means any groundwater monitoring well installed for the specific purpose of determining either the elevation of the water table, or the physical, chemical, biological, or radiological properties of groundwater at the water table or both.

(59) "Well" means any drillhole or other excavation or opening in the ground constructed for the purpose of obtaining or monitoring groundwater.

(60) "Well point" means a screening device, equipped with a point at one end, that is meant to be driven into the ground; it may be used for water quality monitoring.

(61) "Well depth" means the distance from the land surface to the bottom of the well screen or drillhole.

(62) "Well screen" means a filtering device used to retain the primary or natural filter pack; usually a cylindrical pipe with openings of a uniform width, orientation, and spacing.

(63) "Well volume" means the volume of water standing in the well casing.

(64) "Zone of saturation" means a hydrologic zone in which all the interstices between particles of geologic material or all of the joints, fractures, or solution channels in a consolidated rock unit are filled with water at pressure greater than that of the atmosphere.